# The Magdeburg Hemispheres

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## TOOLS:

- Drill (1)
- Marking pen (1)
- Match (1)
- Nail (1)
- Scissors (1)

## PARTS:

- Cake pans (2)
  *not nonstick*
- Cabinet knobs (2)
- Wood screws (2)
  *to fit knobs. The mounting screws that come with the knobs are probably too long.*
- Newspaper (8 sheets)
- Water (1)
- Silicone cement (1)
- Cotton balls (1 bag)
- Aluminized tape (1)
- Cigarette lighter fluid (1)

## SUMMARY

In the spring of 1654, German scientist Otto von Guericke staged a dramatic demonstration of his new invention, the vacuum pump. Guericke was the mayor (Bürgermeister) of Magdeburg, and he arranged for a public demonstration in the town square. Two teams of 15

horses would try to pull apart two 20"-diameter metal hemispheres.

The hemispheres were not bolted, welded, glued, or otherwise mechanically connected to one another. Instead, the air inside the sphere had been evacuated by means of von Guericke's new vacuum pump. Strain and pull as they might, the force of the vacuum was stronger than the 30 horses — the teams could not part the sphere.

The Magdeburg Hemispheres, as they came to be known, were a pair of large copper hemispheres with mating rims. Von Guericke applied a thick coating of grease to the rims, attached his new vacuum pump apparatus, and pumped out a good bit of the air, producing a strong vacuum inside.

How hard would those horses have to pull in order to separate the hemispheres? To figure this out, first calculate the area of a 20"-diameter circle: $\pi r2 = \pi 102 = 314$ square inches (in2). Air pressure at sea level is about 14.7 pounds per square inch (psi, or lbf/in2). If von Guericke's pump was capable of pulling a near-vacuum of about 1lbf/in2, then the force required to pull the halves apart is 314in2 × (14.7–1) lbf/in2 = 4,300 pounds of force.

The hemispheres could sustain a load of well over 2 tons!

It's easy and fun to build your own Magdeburg Hemispheres, although we'll use aluminum cake pans instead of copper hemispheres. Hooking up horses to pull the pans apart is definitely optional!

## Step 1 — Attach the knobs to cake pans.

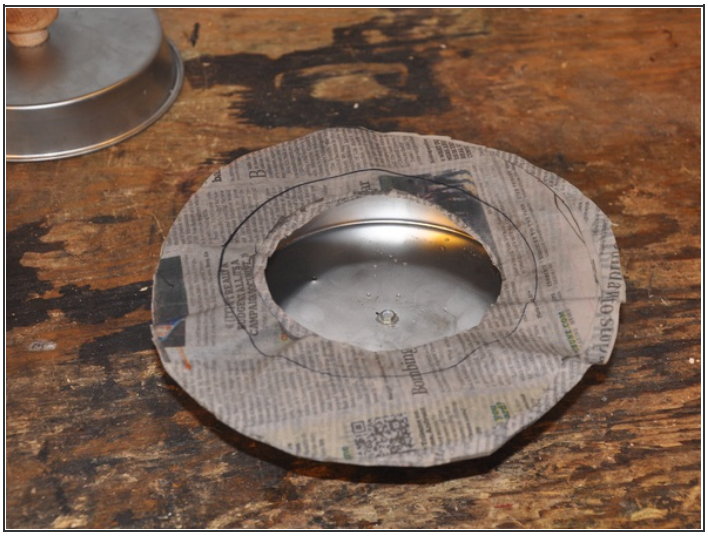


- Drill a hole in the center of each cake pan the same diameter as the screws you'll use with the cabinet knobs.
- Place a dollop of silicone sealant on each hole. Insert the screws through the holes and into the knobs, and tighten them. The silicone will seal around the screws, making the connections airtight.

## Step 2 — Make the vacuum release port.

- Place one cake pan on a wooden block. Mark a point about 2" from the center knob and drill a 1/8" hole. Cover the hole with a piece of aluminized tape.

## Step 3 — Make the gasket.



- Stack 8 sheets of newspaper, mark a circle slightly larger than the cake pan, and then cut out the paper circles.
- Cut a 4"-diameter doughnut hole in the center of the paper circles. Stack them neatly and soak them briefly in water. Remove them from the water as soon as the inside paper circles are wetted.
- Lay the paper gasket across one cake pan as shown.

## Step 4 — Pull a vacuum.

- Pour about 3 drops of fuel on a small cotton ball and place it near the center of the cake pan, but away from the vacuum release port. Carefully light the cotton ball with a long match or fireplace lighter.
- Place the other cake pan atop the paper gasket, taking care to align the rims of the pans, one on top of the other.
- The burning cotton ball produces water vapor. The vapor quickly condenses into liquid, producing a partial vacuum inside the container.
- **CAUTION**: The burning cotton ball will locally heat the cake pans; avoid this area with your bare hands.

## Step 5 — Bring in the horses.


- Pull on the knobs to separate the 2 pans. The halves will not separate, even if substantial force is applied!
- Use the nail to poke a hole in the aluminum tape covering the vacuum release port. Once the seal is broken, the 2 halves will release.
- This German 50-pfennig note celebrates Otto von Guericke's famous demonstration of a vacuum — two teams of horses could not separate the hemispheres.

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